

REVIEW ARTICLE

## One Health training, research, and outreach in North America

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**Background:** The One Health (OH) concept, formerly referred to as ‘One Medicine’ in the later part of the 20th century, has gained exceptional popularity in the early 21st century, and numerous academic and non-academic institutions have developed One Health programs.

**Objectives:** To summarize One Health training, research, and outreach activities originating in North America.

**Methods:** We used data from extensive electronic records maintained by the One Health Commission (OHC) ([www.onehealthcommission.org/](http://www.onehealthcommission.org/)) and the One Health Initiative ([www.onehealthinitiative.com/](http://www.onehealthinitiative.com/)) and from web-based searches, combined with the corporate knowledge of the authors and their professional contacts. Finally, a call was released to members of the OHC’s Global One Health Community listserv, asking that they populate a Google document with information on One Health training, research, and outreach activities in North American academic and non-academic institutions.

**Results:** A current snapshot of North American One Health training, research, and outreach activities as of August 2016 has evolved.

**Conclusions:** It is clear that the One Health concept has gained considerable recognition during the first decade of the 21st century, with numerous current training and research activities carried out among North American academic, non-academic, government, corporate, and non-profit entities.

Keywords: *One Health; research; training; human; animal; environmental*

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The One Health concept is a global strategy for expanding interdisciplinary collaborations and communications in all aspects of health care for humans, animals, and the environment. The synergism achieved will advance health care for the 21st century and beyond by accelerating biomedical research discoveries, enhancing public health efficacy, expanding the scientific knowledge base, and improving medical education and clinical care. When properly implemented, it will help protect and save millions of lives in our present and future generations (1).

Recognizing that human health (including mental health via the human–animal bond phenomenon), animal health, and ecosystem health are inextricably linked, One Health seeks to promote, improve, and defend the health and well-being of all species by enhancing cooperation and collaboration between physicians, veterinarians, and

other scientific health and environmental professionals and by promoting strengths in leadership and management to achieve these goals (2).

While early global discussions about the overlaps of the human and animal medical professions occurred during the 19th and 20th centuries and have continued to present day, focused conversations about One Health began in North America in the early 2000s. After the September 11, 2001 terrorist attacks, the US government gave each state a small amount of money for emergency preparedness. North Carolina used these funds to launch an annual, trans-disciplinary symposium series. The first one in 2002 did not use the term, but every year from 2003 onward (except 2011) the North Carolina Department of Agriculture and Consumer Services has partnered with local academic institutions to oversee an annual One Medicine Symposium (3). In September 2004, the Wildlife

Conservation Society (WCS), which is based in New York, brought together health experts from around the world at Rockefeller University to discuss the movement of diseases among humans, domestic animals, and wildlife. From that meeting emerged the ‘Twelve Manhattan Principles’ (4), urging world leaders, civil societies, the global health community, and institutions of sciences to holistically approach epidemic/epizootic disease prevention and ecosystem integrity. This event was followed by further One Health meetings organized by the WCS later in 2004 (Bangkok), 2005 (China), 2007 (Brazil), and 2009 (Brazil) (5).

The One Health Initiative (OHI) Autonomous *pro bono* team, a group of individual One Health advocates, was established in 2006 (6, 7). The group began writing newspaper Op-Eds, publishing One Health articles in professional journals, and gathering and distributing One Health information. Also in 2006, a group of One Health advocates began a discussion series in Washington, DC, which is now known as the One Health Academy (see Non-Academic One Health Training, Research, and Outreach section).

One of the earliest particularly efficacious efforts to raise One Health awareness in the Americas was the partnership in 2007–08 between the American Medical Association (AMA), the American Veterinary Medical Association (AVMA), and a number of other professional societies to establish a One Health Initiative Task Force (OHITF) comprising stakeholders from a range of disciplines (8). These professionals sought to define One Health and make recommendations for advancing the concept. Among those recommendations was the creation of an organization that would spearhead necessary collaborations; in 2009, the Rockefeller Foundation donated funds to help establish the One Health Commission (OHC), a 501(c)(3) non-profit organization, for that purpose. In October 2008, the OHI team launched the OHI website and began disseminating grassroots OH information, news, publications and upcoming events items worldwide and listing international individuals and organizations that philosophically support and embrace the One Health concept (6, 9).

The One Health concept made considerable progress in 2009. Among the advances in that year, there was a partnership between the OHC and the National Academy of Sciences to hold an OHC Summit in Washington, DC (10). The US Centers for Disease Control and Prevention (CDC) established a One Health Office (11), and the US Agency for International Development (USAID) began its Emerging Pandemic Threats (EPT) Program designed according to a One Health model (12). The EPT Program, in partnership with US and international universities, initiated the One Health Workforce Project to train current and future OH professionals (13).

In May 2010, the CDC, in close collaboration with the World Organisation for Animal Health (OIE), the Food

and Agriculture Organization (FAO) of the United Nations, and the World Health Organization (WHO), hosted a meeting in Stone Mountain, GA, USA, entitled ‘Operationalizing “One Health”: A Policy Perspective – Taking Stock and Shaping an Implementation Roadmap’. The specific goal of the Stone Mountain meeting was to identify clear and concrete actions to move the concept of One Health from vision to global implementation [see the Executive Summary of the Stone Mountain meeting for an excellent history of the progress of One Health up to 2010 (14)].

OHIs were beginning in academic settings also: among the universities that began holding One Health/One Medicine symposia and discussion series were Michigan State University (2010) and Iowa State University (2010) (15, 16). North Carolina’s One Health Collaborative (NC OHC) of interinstitutional faculty from Duke University, the University of North Carolina at Chapel Hill (UNC), and North Carolina State University (NCSU) and individuals from the Research Triangle Park region also began overseeing a One Health Intellectual Exchange Group discussion series in 2009 (17).

Interestingly, in 2010, an important unique educational publication to assist young people with their early education was produced by the Center for Technology in Teaching and Learning, Rice University, Houston, TX (USA), in partnership with the Center for Biodefense and Emerging Infectious Diseases at the University of Texas Medical Branch, Galveston, TX, USA. It evolved into the creation of a freely distributed *MedMyst* magazine ‘One Health Initiative’ pamphlet (18).

In 2012, the University of Minnesota was funded by the Rockefeller Foundation to create a catalog of One Health activities, which was shared with the OHC to initially populate a Who’s Who in One Health web page listing organizations that were actively leading One Health efforts (19, 20). This page is still a work in progress. The year 2012 also saw the creation of a One Health Coordinating Office within the US Department of Agriculture Animal Plant Health Inspection Service (USDA APHIS) (21), and the National Institute of Animal Agriculture hosted a conference on One Health and Antimicrobial Resistance (22).

In late 2015, the OHC, the OHI, and a new international group, the One Health Platform Foundation (23), partnered to create an annual Global One Health Day (24). Designed to raise global awareness of the One Health approach and the many issues that fall under its purview, the inaugural event was celebrated on November 3, 2016, giving individuals and groups from around the world – from academic to corporate and non-profit organizations, from students to established professionals – the opportunity to implement One Health projects and special events (24). In addition, the OHC and OHI jointly established a One Health Education project, ‘Preparing

Society to Create the World We Need through ‘One Health’ Education’, in June 2016 (25).

As discussed above, interest in One Health and the development of One Health activities are by no means confined to North America. This review is just one of a series of review articles on One Health activities worldwide. Other geographic areas are covered in separate reviews, compiled by One Health leaders most familiar with the activities going on in their respective regions. In this review, we seek to identify One Health training, research, and educational outreach activities currently operating within North America, within traditional academic as well as non-academic settings. Note that the Caribbean is covered in the article on One Health in South America.

## Methods

Information for this review article was derived from the extensive One Health community records of the OHC and the OHI Autonomous *pro bono* team, One Health web searches conducted in the fall of 2016, and the professional contacts and experiences of the authors. Both the OHC (since 2009) and OHI (since 2006) have worked in global One Health endeavors for more than 10 years and are currently integrated into a wide network of One Health stakeholders.

Furthermore, a call for information was disseminated to the OHC Global One Health Community listserv. Participants were asked to populate an online Google Document with information on One Health training and research activities (entries were verified and One Health activities were summarized). Some of the most noteworthy programs are highlighted in this article, and additional programs and courses are listed in Table 1. The authors learn new One Health activities almost daily. Full text descriptions of all One Health activities in North America would markedly exceed this journal’s word count limits.

The authors acknowledge that there are likely additional One Health training, research, and outreach efforts in North America that were inadvertently missed in this review. Readers are encouraged to share additional information on their One Health activities in North America with the corresponding author to update this listing and expand future summaries.

## Results and discussion

Table 1 lists academic One Health training programs and Fig. 1 shows their geographic distribution. As discussed earlier, the more traditional setting for One Health training and research is in academia, but non-academic players also recognize the growing interest in One Health and have responded enthusiastically. Non-academic One Health leadership activities, including those initiated by state and national governmental agencies, are listed in Table 2.

## Academic One Health training opportunities

Certificates, Masters, and PhD programs

Thirteen institutions in North America offer Major/Minor, Certificate, Masters, or PhD programs grounded in the One Health concept. More information about their specific activities is presented in Table 1. The Ross University College of Veterinary Medicine offers a Master of Science (MSc) One Health degree; the Virginia-Maryland College of Veterinary Medicine offers a Masters of Public Health (MPH) grounded in ‘an interdisciplinary One Health approach’; and Tufts University offers a Masters in Conservation Medicine (MCM) that uses a One Health approach. Cornell University will offer an MPH degree with a focus on epidemiology, food systems, infectious disease, and sustainability starting in fall 2017. The University of Florida offers a Master of Health Sciences (MHS) in One Health as well as what is believed to be the first One Health PhD program created and developed originally by one of the coauthors of this article (G.C.G.). The University of Washington offers its MPH students a training program in Occupational Health at the Human-Animal Interface (OHHAI) that promotes a One Health approach. The University of Tennessee operates a joint DVM-MPH program that integrates One Health concepts into its curriculum. Similarly, two University of Illinois campuses, Chicago and Urbana-Champaign, have made a partnership to operate a joint doctor of veterinary medicine (DVM)-MPH. At the undergraduate level, the Chicago campus also offers a Bachelor of Public Health degree with a One Health theme, and the University of California, Davis offers a Global Disease Biology major. Berry College offers a One Health minor. Fontbonne University offers an undergraduate One Health Certificate, and in Canada, the University of Saskatchewan offers a Graduate Certificate in One Health.

Academic One Health training, research, and outreach programs

While relatively few academic institutions operate designated degree or certificate programs, many have One Health focused degrees, programs, groups, or initiatives. Due to space reason, in this article we limit this discussion to only the largest programs (listed in alphabetical order) with additional institutions known to provide significant One Health training listed in Table 1.

Duke University is home to the Duke One Health Training Program and Duke One Health Research Team. During the last 9 years, this One Health Training Program (initially offered at Iowa State University and then at the University of Florida) has trained three cohorts of One Health trainees. The 4th annual program will be held on May–June of 2017. The program involves 3.5 weeks of intense graduate training in One Health (four courses) and often engages international professional and graduate students from 10 or more countries (26).

Table 1. Academic One Health training, research, and outreach activities in North America, Stroud, USA, 2016

School	State/Province	One Health activities
Canada		
Concordia University	Quebec	Offers MOOC (Massive Open Online Course) called 'Wicked Problems, Dynamic solutions: The Ecosystem Approach and Systems Thinking'
University of Saskatchewan	Saskatoon	Graduate Certificate in One Health, One Health Initiative, OH Research Symposium, One Health Leadership Experience (conference)
University of Calgary	Alberta	Faculty of Veterinary Medicine Seminar: Using a One Health Approach to Reduce Pandemic Risk and Promote Global Health
University of Guelph	Ontario	2016 One Health Seminar Series sponsored by the Centre for Public Health and Zoonoses (CPHAZ), One Health undergraduate student travel grants
United States		
Auburn University	Alabama	Cancer research integrating One Health/One Medicine, Zohdy Lab
Baylor College of Medicine	Texas	Seminar in Tropical Medicine: One Health cross-listed at Rice University
Berry College	Georgia	Undergraduate One Health Minor, One Health Center
Colorado State University	Colorado	One Health Institute, One Health Research & Development Program
Columbia University	New York	The Center for Infection and Immunity (collaborates with the EcoHealth Alliance), One Health laboratory research, Student One Health Initiative
Cornell University	New York	MPH degree with a focus on epidemiology, food systems, infectious disease, and sustainability (starting Fall 2017), Zoonotic Disease Symposium, Research focus at Atkinson Center for a Sustainable Future, Baker Institute for Animal Health
Duke University	North Carolina	One Health Training Program (Summer), Duke One Health Research Laboratory, One Health Team, Co-host of One Health Intellectual Exchange Course
Emory University	Georgia	Research at Antimicrobial Resistance Center
Fontbonne University	Missouri	Undergraduate One Health Certificate
Georgetown University	District of Columbia	Sponsor of One Health Commission (OHC) with representative on the OHC Board, Graduate Course: 'One Health: US Policy for a Global Challenge'; Medical and Law Schools jointly organized One Health Symposium in 2015 and again for global One Health Day 2016
Iowa State University	Iowa	College of Veterinary Medicine supports One Health Initiative, One Health Conference with Texas A&M
Kansas State University	Kansas	Developing One Health courses, education programs and local research programs at the K-12, undergraduate, and graduate levels
Lehigh University	Pennsylvania	'Lehigh in Bermuda: Oceans and Human Health' Summer Program
Lincoln Memorial University (LMU)	Tennessee	One Health Program at College of Veterinary Medicine (LMU-CVM)
Michigan State University	Michigan	Inst. of International Health supports OHI, College of Veterinary Medicine to launch Nepal One Health in 2017, College of Communications, Arts, Sciences symposia on OH & Emerging Communications Technologies
Midwestern University	Arizona	Plans to augment interprofessional courses to incorporate OHI principles
Mississippi State University	Mississippi	One Health Challenge, Uganda One Health Trip

Table 1 (Continued)

School	State/Province	One Health activities
North Carolina State University	North Carolina	Research at College of Veterinary Medicine, Co-host of North Carolina One Medicine Symposium, Co-host of One Health Intellectual Exchange Course, Masters in Public Health – Veterinary Epidemiology in partnership with the University of North Carolina Gillings School of Global Public Health
Ohio State University	Ohio	One Health Summer Institute, OHI at College of Veterinary Medicine, Ohio State/Ethiopia One Health Partnership
Oklahoma State	Oklahoma	Sponsored first One Health Conference in Oklahoma, 2012
Oregon State University	Oregon	One Health seminars and research
Penn State University	Pennsylvania	Soil Health for One Health Initiative, One Health Soils course offered by College of Agricultural Sciences
Princeton University	New Jersey	Undergraduate course in One Health
Purdue University	Indiana	One Health Lectures
Rice University	Texas	Seminar in Tropical Medicine: One Health cross-listed at Baylor College of Medicine, MedMyst Magazine
Ross University College of Veterinary Medicine	New Jersey-St Kitts Island	Sponsor of the One Health Commission with representative the on OHC Board, One Health Center for Zoonoses and Tropical Veterinary Medicine, Master of Science (MSc) One Health Degree Program
South Dakota State University	South Dakota	One Health Coalition, One Health Research Program
Stanford University	California	Stanford One Health 2016 Symposium and Stanford 2014 Zoobiquity Research Symposium hosted by Comparative Medicine Department
St. Louis University School of Medicine	Missouri	One Health One Medicine Fair, One Health Interest Group
Texas A&M University (TAMU)	Texas	College of Vet Med is sponsor of OHC, extensive One Health – TAMU program, One Health Round Table, One Health Clinic, Undergraduate degree program with concentration in Oceans and One Health, One Health Summer Research Program
Tufts University	Massachusetts	Fellowship Programs, One Health Undergraduate course, Students for One Health, Student-led One Health Day, Masters in Conservation Medicine (MCM), Research Services, Peer One Health Collaborative
Tuskegee University	Alabama	Collaboration between School of Veterinary Medicine and School of Nursing and Allied Health to promote One Medicine – One Health
University of California, Berkeley	California	Student-initiated DeCal undergraduate course ‘One Health for Action: Integrating Human, Animal, and Environmental Health’
University of California, Davis	California	One Health Institute, School of Veterinary Medicine, Global Disease Biology major, One Health Field Course, One Health Center for research, Calvin Schwabe Project, One Health Student Summer Research Programs/ Grants
University of Florida	Florida	MHS, PhD in One Health, One Health Certificate Program (former)
University of Georgia	Georgia	Division of One Health, One Health Seminar Series and Symposia
University of Illinois, Chicago	Illinois	DVM/MPH joint degree program with Urbana campus, Bachelor of Public Health with One Health theme
University of Illinois, Urbana-Champaign	Illinois	DVM/MPH joint degree program with Chicago campus, Center for One Health Illinois, One Health Day (organized by Public Health Club)
University of Iowa	Iowa	Hosted One Health Conference 2016, operates Center for Emerging Infectious Diseases

Table 1 (Continued)

School	State/Province	One Health activities
University of Minnesota	Minnesota	Partner of Global Initiative Food Systems Leadership (GIFSL), Global One Health Initiative, ICOMOS International Conference: One Med One Science, One Health Workforce Project
University of Missouri- Mizzou Advantage	Missouri	Sponsor of the One Health Commission, One Health/One Medicine research and programming, part of WAMCOH
University of North Carolina	North Carolina	Co-host of One Health Intellectual Exchange Course
University of Pennsylvania	Pennsylvania	OHI at School of Veterinary Medicine
University of Tennessee	Tennessee	DVM-MPH integrating One Health concepts
University of Washington	Washington	Center for One Health Research, Human Animal Medicine Project, School of Public Health and Medicine, University of Washington Center for OH Research Blog, MPH Occupational Health at the Human-Animal Interface (OHHA) Training Program
University of Wisconsin-Madison	Wisconsin	Kibale EcoHealth Project, One Health Portal
Virginia–Maryland College of Veterinary Medicine	Virginia	Research focused on One Health, MPH program grounded in an interdisciplinary ‘One Health’ approach
Virginia Tech	Virginia	One Health library guide
Washington State University	Washington	School for Global Animal Health
Washington University in St. Louis	Missouri	One Health seminar called ‘The Big Bet: How Linking Human and Veterinary Medicine Improves Health Across Species’
Western University of Health Sciences	California Oregon	Division of Global and Community Health aims to foster research, education, and training to address issues that bridge animal, human, and environmental health
Yale University	Connecticut	School of Public Health research, Student funding opportunities
Student for One Health (SOH) groups		
Auburn University	Alabama	Students for One Health Club
Brown University	Rhode Island	Alpert Medical School Students for One Health
Colorado State University	Colorado	One Health Club
Cornell University	New York	Veterinary School Public Health/One Health Club
Kansas State University	Kansas	Public Health Club
Iowa State University and University of Iowa	Iowa	Students working for One Health (partnership with University of Iowa)
Michigan State University	Michigan	Students for One Health
Midwestern University	Arizona	One Health Student Club
Mississippi State	Mississippi	One World – One Health & Public Health clubs
North Carolina State University	North Carolina	One Health Student Initiative
Ohio State University	Ohio	Buckeyes without Borders
Purdue University	Indiana	Purdue One Health Club
St. Louis University	Missouri	One Health Interest Group
Texas A&M University	Texas	Student One Health Association
Tufts University	Massachusetts	New England Students for One Health, Undergraduate One Health Peer Health Collaborative

Table 1 (Continued)

School	State/Province	One Health activities
University of California, Berkeley	California	One Health Student Initiative, DeCal undergraduate course mentioned above
University of California, Davis	California	Students for One Health (Vet School and Undergraduate)
University of Georgia	Georgia	Student One Health Club
University of Illinois – Urbana-Champaign	Illinois	Student Public Health Association co-sponsor of One Health Day
University of Iowa	Iowa	Students working for One Health (partnership with Iowa State)
University of Pennsylvania	Pennsylvania	College of Veterinary Medicine One Health Club (PennVet)
University of Tennessee	Tennessee	SCAVMA One Health Club
Washington University in St. Louis	Missouri	Student One Health Interest Group
Western University of Health Sciences College of Veterinary Medicine	California Oregon	Student clubs
Virginia Tech University and Virginia-Maryland College of Veterinary Medicine	Virginia	VT One Health Club

A version of this table that includes URL links active at the time of publication is available as an online Supplementary file.

OHC, One Health Commission; OHI, One Health Initiative; MPH, Masters of Public Health; MHS, Master of Health Sciences, LMU-CVM, Lincoln Memorial University College of Veterinary Medicine.

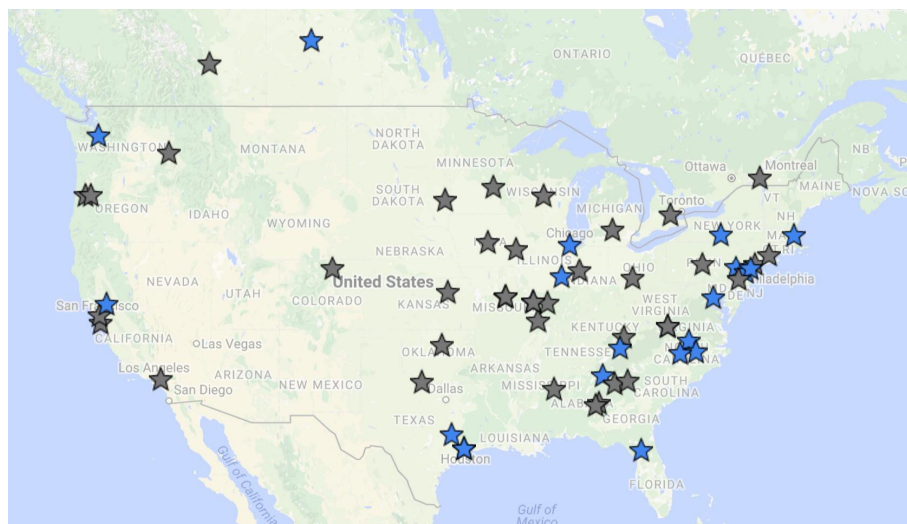
Duke faculty, along with faculty from NCSU, the UNC, and other institutions in the Raleigh-Durham-Chapel Hill Research Triangle Park area, participate in the NC OHC. Since 2010, this group has overseen a One Health Intellectual Exchange Group discussion series at the North Carolina Biotechnology Center and an interinstitutional course called One Health: Philosophy to Practical Integration, cross listed at Duke University, NCSU, and UNC and offered to area graduate and undergraduate students.

Duke University also partners with Duke-National University of Singapore (NUS) Medical University Singapore and Duke Kunshan University, China to exchange graduate students and professionals conducting One Health training and research (27). Duke University has a National Institute of Health (NIH)-funded D43 training program for teams of US and Mongolian professionals to conduct 2 years of One Health zoonotic disease research. Finally, Duke University is conducting NIH-funded R01 of zoonotic influenza transmission with multiple research institution partners in China (28).

Ohio State University's (OSU) recently retired dean of the College of Veterinary Medicine (CVM), Dr. Lonnie J. King [DVM, MS, MPA] has been an extraordinary One Health leader. After chairing the 2007–2008 OHITF, Dr. King was instrumental in taking the One Health conversation into US national arenas. Among his various efforts, one was organizing One Health workshops in the National Academy of Sciences (29). Under his leadership, the OSU CVM expanded programs that take an integrated approach to addressing animal, environmental, and human health, and it offers a MPH with a Veterinary Public Health specialization (30).

Individuals and colleges outside the CVM have also expanded their OH research, training, and outreach activities. Ohio State faculty and staff have created iTunes U courses related to their One Health projects (31). An OSU student organization, Buckeyes Without Borders, was formed in 2009 to bring together graduate students from a wide range of disciplines, including audiology, dentistry, medicine, nursing, occupational therapy, optometry, pharmacy, physical therapy, public health, social work, speech language pathology, and veterinary medicine (32).

OSU's health sciences colleges have gained particular recognition. The Ohio State Global OHI was launched in 2009, and it partnered with Ohio State's seven health sciences colleges with 19 institutes in Ethiopia and the rest in the United States. Training students (from Ethiopia and the United States) in One Health Summer Institutes is one of the OSU Health Sciences-Ethiopia Partnership's priority areas to build capacity and strengthen collaboration (33). The Initiative has brought in additional partners and begun to extend its reach into eastern Africa, Brazil, and Southeast Asia (34).



*Fig. 1.* Location of known academic One Health training, research, and outreach programs in North America as of August 2016. Blue stars denote universities that offer formal One Health, academic credit-earning programs, including Undergraduate majors/minors as well as Certificate, Masters, or PhD programs. Gray stars denote universities with no academic credit-earning program but with other significant One Health training, research, or outreach activities.

OSU's efforts have involved not only students but also the broader One Health community. In 2015, OSU was a co-organizer of the Third International Congress on Pathogens at the Human Animal Interface (ICOPHA) (35). The OSU Extension Division organizes One Health conferences where public health officials, veterinarians, and extension workers can learn about and discuss issues relevant to public, veterinary medical, and environmental health (36).

The Texas A&M University (TAMU) OHI was started in 2011 by the deans and faculty of the College of Veterinary Medicine & Biomedical Sciences and the College of Medicine (37). A One Health program coordinator and an assistant dean were hired in 2012. The Initiative provides a One Health Learning Community for undergraduate students aimed at introducing the One Health concept to students early in their educational careers. For faculty, a TAMU One Health Grand Challenge funding program was initiated in 2014; four major OH research themes were identified, and a plan was implemented to bring faculty from across TAMU into collaborative, inter-/transdisciplinary research partnerships. Information on some of these partnerships, along with early outcomes, can be found on the TAMU website (38).

The TAMU One Health On-Campus Summer Research Program provides an opportunity for two professional and/or graduate students to participate in a 13-week hands-on research program at the university. One Health educational and student research opportunities are available across the campus. One Health Student Travel Grants are awarded to selected students to present One Health research at scientific conferences. The TAMU OH program oversees a One Health Seminar Series (39) and has

implemented outreach programs in Nicaragua and China. A final opportunity for One Health outreach at TAMU is the Student One Health Association (SOHA), which is open to all undergraduate, graduate, and professional students (40).

The University of California, Davis (UC Davis) One Health Institute was created in 2009 as a result of a strong commitment to the One Health approach (41). The institute leads the PREDICT Project which is a part of the USAID EPT Program. In partnership with USAID, WCS, EcoHealth Alliance, Metabiota, and the Smithsonian Institution, PREDICT researchers contribute to global surveillance efforts to detect pathogens of pandemic potential and prevent spillover between wildlife and people (42). UC Davis' Wildlife Health Center operates the OHI Lab, which serves as a primary research facility for PREDICT (43).

The One Health Institute leads the Health for Animals and Livelihood Improvement (HALI) Project, a collaborative, capacity-building program that brings together researchers from the United States and Tanzania to study the effects of zoonotic diseases and water management practices on individuals living within Tanzania's Ruaha ecosystem (44). UC Davis is also home to the Calvin Schwabe Project, which has been named in honor of the former UC Davis School of Veterinary Medicine professor (Calvin Schwabe) who coined the term 'one medicine' (40). The Calvin Schwabe Project offers a wide range of OH opportunities to veterinary students, encouraging them to approach their future careers with an appreciation of the interconnectedness of animal, environmental, and human health (45).

Outside the CVM, the UC Davis Global Health Department program offers One Health Graduate and



Table 2. Non-academic One Health training, research, and outreach activities in North America, Stroud, USA, 2016

School	Country	One Health activities
Professional associations, non-governmental and non-profit organizations		
American Association of Veterinary Medical Colleges (AAVMC)	USA	One health case studies for interprofessional education
American Medical Association	USA	Partnered in the establishment of the One Health Initiative Task Force. Sponsor of the One Health Commission with representative on the OHC Board of Directors
American Society of State and Territorial Health Officials (ASTHO)	USA	National nonprofit representing public health agencies across the US. Seeks to inform public policy and improve health. Hosts OH Webinars and has established a One Health Committee
Animal Medical Center (AMC-NY)	USA	Not-for-profit academic veterinary hospital; host of AMC OH Conference 2015: Connecting Human and Veterinary Medicine, A Comparative Approach to Cancer Care
American Veterinary Medical Association (AVMA)	USA	Partner in establishment of OHITF. Sponsor of OHC. Provides OH web page and promotional support. Provides veterinarians with information, resources, and guidance on OH issues
Association of American Medical Colleges	USA	Sponsors the One Health Commission with representative on the OHC Board of Directors
EcoHealth Alliance	USA	Formerly known as Wildlife Trust, co-sponsor of International One Health/EcoHealth meeting 2016, led by early One Health leaders
EcoHealth	USA	Conferences and regional symposia; International Association for Ecology & Health journal – subtitle: One Health, Ecology and Health, Public Health
Farm Foundation (NFP)	USA	Sponsor of OHC, convenes agriculture and food systems stakeholders for discussion, led 13 meetings on Antimicrobial Stewardship to prepare animal agriculture industry for new regulations
Georgia Aquarium	USA	Vanguard Sponsor of OHC. Private, non-profit organization that carries out OH research. One Ocean – One Health program. Proposed building of a One Ocean One Health Research Institute
Global Alliance for Rabies Control (GARC)	USA	Private, non-profit organization whose main focus is on countries in Asia and Africa where rabies is a major public health issue. Hosted student OH Rabies Grand Challenge competition in 2014
Global Initiative Food Systems Leadership (GIFSL)	USA	Trains emerging leaders of the food system through a variety of programs and events. Partnered with UMN to construct Catalog of OH Activities
Human Animal Bond Research Initiative (HABRI)	USA	Sponsor of the One Health Commission with representative on the OHC Board of Directors, educates public on the mutual benefits of pet ownership
Infectious Diseases Society of America	USA	Sponsor of the One Health Commission with representative on the OHC Board of Directors
Institute for Global Health & Health Policy	USA	501(c)3 nonprofit organization that organizes One Health workshops in marine & terrestrial conservation medicine for students and professionals
International Food Information Council (IFIC)	USA	Sponsor of the One Health Commission with representative on the OHC Board of Directors
International Society for Infectious Diseases (ISID)	USA	Oversees ProMED, a free Internet-based reporting system for dissemination of information on infectious disease outbreaks; hosts 2 biennial meetings, IMED and ICID, OH topics
Kansas City Area Life Sciences Institute	USA	Sponsor of the One Health Commission with representative on the OHC Board of Directors, leads annual local One Health conferences
Missouri Medical Association	USA	Cooperation with Missouri University College of Veterinary Medicine and School of Medicine, published landmark One Medicine journal issue in 2013/14

Table 2 (Continued)

School	Country	One Health activities
National Academy of Science	USA	Co-hosted One Health Commission workshop in 2009 and many related workshops since, Institute for Laboratory Animal Research operates fellowship program for OH researchers from Pakistan
National Link Coalition	USA	Network of professionals in animal welfare and human services; works at human-animal-environment interface. OH education on link between domestic violence and animal abuse
National Marine Mammal Foundation (NMMF)	USA	NMMF's Translational Medicine & Research Program has adopted an OH approach
National Pork Board	USA	Sponsor of the One Health Commission with representative on the OHC Board of Directors
North Carolina One Health Collaborative	USA	Sponsors OH Intellectual Exchange Group Discussion series, bringing local professionals and students together. Oversees Interinstitutional OH course cross listed at Duke, NCSU and UNC
One Health Academy	USA	Based in Washington, DC; advances One Health through motivating, mentoring, and networking
OHC	USA	A globally focused 501(c)(3) organization chartered in Washington, DC; connects OH advocates, creates networks and collaborations, and educates about OH and OH issues
OHI <i>Autonomous pro bono</i> team	USA	A group of One Health advocates who gather and disseminate One Health information, seeking to unite human and veterinary medicine with ecosystem health
One Health Organization	USA	Offers on-site veterinary services for housebound elderly, One Health Workforce Development Program trains students to prevent the spread of disease between animals and humans
Ovarian Cancer Symptom Awareness (OCSA)	USA	Works within the veterinary community to expand public awareness of the symptoms of human ovarian cancer, sponsors training of dogs to sniff out ovarian cancer
Pet Partners (formerly Delta Society)	USA	International non-profit organization dedicated to promoting and demonstrating that positive human-animal interactions improve people's physical, psychological, and emotional lives
Puccini Foundation for Comparative Oncology	USA	Raises awareness of and money for comparative oncology research
Reunión Interamericana a Nivel Ministerial (RIMSA)	USA	Convenes Ministers of Health and Agriculture from Pan-American Health Org. Member states
St Louis Zoo	USA	Institute for Conservation Medicine (ICM) leads scientific projects that address diseases shared between animals and humans, Zoo hosts OH Fairs and held 2016 Inaugural OH Symposium
Veterinarians Without Borders (VWB/VSF)	Canada	Community-based animal health programs, training and education for veterinarians
Washington U/AuburnU/UMissouri Consortium for One Health (WAMCOH)	USA	Sponsor of the One Health Commission with representative on the OHC Board, focus on comparative medicine and translational research
World Small Animal Veterinary Association (WSAVA)	Canada	World Congress and continuing education programs, WSAVA One Health Committee, rabies vaccination campaign in Africa, One Health conferences
Zoobiquity Initiative	USA	Book on the connection between animal and human health, annual conference bringing together scientists and clinicians from human and animal medicine
Governmental agencies		
CDC One Health Office	USA	OHO promotes OH concept and guides CDC OH approaches; operated by Div. of High Con-sequence Pathogens & Pathogenesis, Nat'l Center for Zoonotic & Emerging Infectious Diseases
CDC Stone Mountain Meeting Workgroups	USA	Stone Mountain meetings bring experts together to implement sustainable global One Health collaborations
Idaho Department of Health/Welfare, Division of Public Health	USA	Idaho One Health Consortium, which holds didactic discussion sessions focused on One Health topics

Table 2 (Continued)

School	Country	One Health activities
Maryland Department of Agriculture	USA	Has produced One Health Bulletins since 2011, which it emails to Maryland veterinarians as well as interested public and animal health stakeholders
Minnesota Department of Health	USA	Minnesota One Health Antibiotic Stewardship Collaborative raises awareness/seeks to change behaviors to preserve antibiotics for animal, human, and environmental pathogens
National Park Service	USA	Developing programs to communicate interconnectedness of species, facilitates student research in 'living laboratories' with human/animal/environmental factors, OH working group
North Carolina Dept. of Agriculture and Consumer Service and Dept. of Health/Human Services	USA	Oversees North Carolina One Medicine Symposium, an annual conference for a wide range of OH stakeholders, hosted in partnership with NC universities and APHIS
One Health Awareness Kentucky (OHA-KY)	USA	A collaborative effort by representatives from state government agencies, academic institutions, private/non-profit organizations, and federal agencies
South Dakota One Health Working Group	USA	Holds seminars where interested stakeholders discuss health and disease issues shared between animals and humans
Tennessee Department of Public Health	USA	One Health Committee promotes/improves health of animals and humans by enhancing cooperation between departments and providing a forum for discussion of OH issues
USAID Emerging Pandemic Threats Programs (EPT-1&2)	USA	Components include Pathogen Detection, Risk Determination, One Health Institutionalization, Response Capacity, and Risk Reduction; created One Health Workforce Project
USDA APHIS	USA	Transforming National VS to Institutionalize One Health; established One Health Coordination Office to weave OH into all levels of organization
Washington State Department of Health	USA	One Health Initiative, collaborative effort among WA state orgs and universities to increase anti-microbial stewardship, develop surveillance/data systems, raise awareness among professionals
Corporate		
Elanco	USA	Division of Eli Lilly that provides products and knowledge to improve animal health and food production; organized OH Antibiotic Stewardship Summit, invited world OH leaders
CEVA Animal Health	USA	Early sponsor of the One Health Commission; mission to help feed growing global population, prevent zoonoses, and enhance the human-animal bond
Galaxy Diagnostics, Inc.	USA	Based in North Carolina, performs human and animal testing for Bartonella and follows an OH philosophy
Land O'Lakes International Development	USA	Focuses on nutrition and human livelihoods from a 'One Health' standpoint, recognizing that human and animal health/nutrition are interrelated
US BIOLOGIC	USA	A 'One Health' company that looks to disease prevention across animals and humans and pays close attention to ecological factors
Zoetis, Inc.	USA	Global animal health company that takes a OH approach, developing tools and supportive resources to support livestock and promote public health, food safety/security

A version of this table that includes URL links current at time of publication is available as a Supplementary file.

OHITF, One Health Initiative Task Force; OHC, One Health Commission; CDC, Centers for Disease Control and Prevention; USAID, US Agency for International Development; USDA, US Department of Agriculture; APHIS, Animal & Plant Health Inspection Service; UMN, University of Minnesota.

Undergraduate seminars, as well as One Health in Action, an intensive, 4-week field course, teaching students to apply the One Health approach to complex problems (46).

UC Davis has extended its One Health activities to include students within the larger University of California system. The UC Global Health Institute (UCGHI) was established as a partnership between the UC Davis and UC Riverside, but its programs and opportunities are available to students at any of the 10 UC campuses (47). One of the three ‘Centers of Expertise’ initially established within UCGHI was a One Health Center, specializing in research into problems that occur at the ‘human-water-animal-food interface’ (47, 48). The center offers OH Student Research Fellowships to both graduate and professional students interested in integrating a One Health approach into their global health research efforts (49).

The University of Florida’s Emerging Pathogens Institute is home to its One Health Center of Excellence for Research and Training (which was first organized by one of the coauthors of this article (G.C.G)). The center oversees the quarterly online *One Health Newsletter*, which publishes One Health papers as well as event(s) details, to subscribers from a wide range of disciplines (50). The University of Florida’s Department of Environmental and Global Health launched two degree programs that immerse trainees in the One Health concept: an MHS, One Health Concentration, and a PhD of Public Health, One Health Concentration, as mentioned previously (51–53). The summer training program now offered by Duke University was first operated as a Certificate program at the University of Florida under the leadership of Dr. Gregory Gray prior to his move to Duke.

The University of Pennsylvania’s School of Veterinary Medicine (Penn Vet) has had a long established and notable One Health program, and One Health education continues to be a high priority under the current dean, Joan C. Hendricks [VMD, PhD] (54). It is the only veterinary school developed in association with a medical school. The relationship between animal health and human health is the core of its teaching tradition so that students can learn first-hand how veterinary medicine and research impacts human lives as well as the lives of animals. In 2015, in partnership with the Pennsylvania Farm Bureau, a Commonwealth One Health Scholarship was initiated, providing a full tuition subsidy for 4 years of veterinary school at Penn Vet. The first two recipients demonstrated a strong commitment to food animal medicine. For faculty, deans of the four health schools at the University of Pennsylvania – the Perelman School of Medicine, the School of Nursing Science, the School of Dental Medicine, and the School of Veterinary Medicine – annually present a One Health Award for significant, collaborative research conducted by faculty, highlighting those engaged in professional education bridging two or

more of the schools with outreach and innovation in training and service in clinics or to the community.

The University of Saskatchewan sponsors a 3-day One Health Leadership Experience each fall, where as many as 200 professionals from multiple disciplines meet to discuss employing One Health in modern complex problems settings. Participants in this program earn a Graduate Certificate in One Health (55). The University of Saskatchewan also hosts a One Health Research Development Grants Competition that has funded nine projects in 2 years (56).

Students for One Health (SOH) groups have formed all over the world to further One Health education and awareness, often forging paths at their universities and educating academic faculty. They implement local discussions on One Health topics, and some go into local communities to hold One Health ‘clinics’ where health needs of both pets and people are addressed. Students embrace One Health very readily and are not yet entrenched in disciplinary silos. They are extremely comfortable in interacting with students studying in disciplines other than their own. It is very important to give students the chance to form relationships across disciplines very early in their training as these relationships will follow them throughout their careers, increasing their future comfort for working across professions.

Realizing that these students are the next generation of One Health leaders, the OHC supports any student group working for One Health by providing an SOH web page, Who’s Who in SOH page, an SOH listserv (57), and an online meeting platform so that they can connect with each other. Educational opportunities are gathered and posted, and a mentor program is being planned. SOH groups that we are aware of are included at the bottom of Table 1. SOH groups that we are not yet aware of are encouraged to share information about their groups and their One Health activities.

Non-academic One Health training, research, and outreach

As mentioned earlier, One Health education is not confined to a traditional academic setting. As interest in, and the need for, taking a multidisciplinary or transdisciplinary approach to addressing complex problems has grown, visionary researchers and health professionals have sought to integrate One Health approaches into their work. Many non-academic organizations discussed below (and additional ones listed in Table 2), including for-profit corporations, have embraced One Health and are actively leading One Health training and research.

*The Association of American Veterinary Medical Colleges (AAVMC)* maintains and supports a standing One Health Committee and hosted in 2015 a competition of One Health Case Studies, illustrating applications of One Health approaches. These studies, along with

facilitator materials, are available online and free to use for teaching in many settings (58). They are a part of AAVMC's One Health Interprofessional Education Initiative, an effort to integrate One Health training into veterinary degree programs around the United States. The AAVMC demonstrated its commitment to educating about the concept by making One Health the focus of its 2014 Annual Conference, entitled 'One Health in Veterinary Medical Education' (59).

*National US and Canada Veterinary Medical Associations* actively support the One Health concept. The AVMA hosts multiple-day One Health tracts at its annual conventions. The Canadian Veterinary Medical Association (CVMA) has demonstrated its commitment to promoting One Health by making the theme of its 2016 Animal Health Week 'One Health: Animal Health + Human Health + Planet Health' (60).

*The Georgia Aquarium* leads a One Ocean, One Health initiative, making a commitment to recognize the interconnectedness of human, animal, and environmental well-being and not study animals in isolation (61). One of its research and conservation goals is to build the One Ocean One Health Research Institute in Marineland, Florida, which could establish itself as a pioneer of the One Health concept in ocean science (62).

*The Kansas City Area Life Sciences Institute* has led multiple One Health conferences, including a 2016 One Health Innovations Symposium that was hosted in partnership with the Schools of Veterinary Medicine at University of Missouri and Kansas State University. This 2-day symposium focused on the translational and comparative aspects of human and animal medicine (63).

*The One Health Academy*, founded in 2006 in Washington, DC, oversees monthly gatherings of health professionals and government officials interested in dialogue, social engagement, learning, and collaboration. By offering networking opportunities, educational presentations and opportunities for discussion, networking and mentoring, these events allow federal, non-profit, clinical, and private industry leaders to interact directly and form relationships that often lead to collaborations (64).

*The One Health Commission*, created in 2009 as a result of recommendations by the OHITF, is a globally focused 501(c)(3) non-profit organization that seeks to 'Connect' One Health Advocates, to 'Create' networks and teams that can work together across disciplines, and to 'Educate' about One Health and One Health issues (63). Based in the Research Triangle Park region of North Carolina, USA, the Commission is governed by a Board of Directors comprising representatives from organizations that fund its work. It is also supported by individual and corporate donations. It serves as an action arm for One Health, a gateway for active education and exchange of knowledge, sharing of resources, and collaborative projects that reach beyond disciplinary boundaries. Its

volunteer One Health Action Teams identify knowledge and education gaps and take actions to address them. To encourage the next generation of One Health leaderst, the OHC supports SOH groups and includes elected student representatives on its Board of Directors (65).

*The One Health Initiative Autonomous pro bono team* (see Non-Academic One Health Training, Research, and Outreach section).

*The Zoobiquity Initiative and Conferences* were started by Barbara Natterson-Horowitz, MD, a professor of medicine in the UCLA Division of Cardiology at the David Geffen School of Medicine, who noticed the many parallels between human and animal health conditions and set out to raise awareness among her colleagues. In 2011, Dr. Natterson-Horowitz founded the ongoing annual Zoobiquity Conference series to bring together human and animal medicine leaders for direct discussions about how to diagnose and treat the conditions that afflict animals and humans alike. In 2012, Dr. Natterson-Horowitz and coauthor Kathryn Bowers published their book *Zoobiquity* in which they highlighted the many conditions that plague both humans and animals and advocated for a cross-species approach to health care. The Zoobiquity Research Initiative also started a program that brings together UCLA medical students and UC Davis veterinary students for discussions of mutual health care interest (66). This valuable project highlights and promotes many collaborative, comparative medicine/translational medicine research achievements over previous decades.

### **One Health research activities**

As evidenced from Table 1 and the aforementioned discussions, a number of training programs in North America provide opportunities for One Health research. Students and investigators seeking research funding and other opportunities may look to the OHC website which maintains a list of funding and grant opportunities. The Commission also requests that the One Health Community send future opportunities to be posted and shared on this web page (67).

Funding for One Health research has often come from the US government. As of September 2016, a search of the grants.gov website with the keyword 'One Health' will reveal more than 79 previous or currently active funding opportunities. Both the CDC and USDA have formally endorsed One Health (68). The USAID has also devoted financial and human resources to OH research in training; its EPT Programs 1 and 2 have awarded grants to investigators to build a One Health Workforce in developing countries that are most threatened by emerging diseases with animal, environmental, and human health implications. One Health research also receives non-governmental support in the United States: the Gates

Foundation and several universities have sponsored significant One Health research.

The Canadian government has demonstrated its support for One Health. One Health researchers have been successful in applying for grants offered specifically for collaborative/interdisciplinary work. The Collaborative Health Research Projects (CHRP), operated jointly by the Natural Sciences and Engineering Research Council of Canada (NSERC) and Canadian Institutes of Health Research (CIHR), have provided research funding to programs such as the One Health Certificate program at the University of Saskatchewan. Government agencies of Canada are themselves embracing the One Health concept in their programs and research projects: the Public Health Agency of Canada claims to be ‘pursuing activities that are consistent with a One Health approach’, and its Centre for Food-borne, Environmental and Zoonotic Infectious Diseases (CFEZID) hosted the One World One Health Expert Consultation in Winnipeg, Manitoba in 2009 (69, 70). Among the Agency’s One Health-consistent activities are the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS), which takes a One Health approach to combat AMR that ‘spans human, animal, agricultural, food, and environmental sectors’, and FoodNet, Canada, a comprehensive sentinel site surveillance system (71).

## Conclusions

In North America, it is clear that One Health has gained considerable recognition over the past decade and is being rapidly recognized as an efficacious and expeditious approach to address today’s most complex problems. Many One Health stakeholders see it as a means to accomplish the United Nations Sustainable Development Goals and a viable path to planetary health (72). Numerous academic, government, and private partners are providing One Health training and research opportunities. Yet, in our opinion, it is unclear whether the One Health ‘movement’ will evolve into a mainstream ‘discipline’ or remain an ‘approach’ to global public and planetary health as some One Health leaders advocate. Those arguing for the One Health sciences to become a discipline encourage that path because it would provide opportunities for young professionals to pursue careers in One Health. Those arguing against are concerned that we might dilute out the ‘depth’ of training that specialties provide and urge that young professionals choose their discipline, hone their skills, and do their work in a One Health way. It may be that our future path lies somewhere between the two scenarios, with some One Health specialists trained to be experts in the areas that fall at the intersections of animal, environmental, and human health. Only time will tell. Meanwhile, there is an ever growing global understanding and appreciation of the value of the One Health paradigm shift that will make this

bridging across disciplines the default way of doing business at all levels of academia, research, government, policy, and law.

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